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ABSTRACT

The paper reviews factor analytic studies concerning Wechsler Intelligence Scale for Children-Revised (WISC-R) profiles of children with learning disabilities (LD). Considered are the following topics: subtest profiles of backward readers, a sex difference in coding, and derivation and use of grouped subtest scores in profile anlaysis. The author proposes an interpretation of the discrepancies between groups of subtests, and suggests that it is more useful to view the WISC profiles of LD students in terms of three or more main categories rather than two. (CL)

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EVALUATION OF VERBAL, SPATIAL AND NUMERICAL SEQUENCING SCORES IN THE WISC-R, WITH SPECIAL REFERENCE TO CHILDREN WITH READING DIFFICULTIES

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AN EVALUATION OF VERBAL, SPATIAL AND NUMERICAL SEQUENCING SCORES IN THE WISC AND WISC-R, WITH SPECIAL REFERENCE TO CHILDREN WITH READING DIFFICULTIES.

INTRODUCTION

Educational psychologists have for many years used the Wechsler Intelligence Scale for Children (WISC) as the main assessment tool when asked to make recommendations for children with learning difficulties. The test has been used first of all to determine an average level of performance in a variety of cognitive and perceptual-motor tasks which do not depend on the ability to read and write. If an individual's performance in reading or in spelling is found to be significantly poorer than his Wechsler I.Q., this is normally thought to indicate a learning difficulty, which if severe, would warrant some remedial educational intervention. Precise quantitative methods of estimating relative amounts of retardation are not in general use, although regression equations based on a short form of the WISC and the Neale Analysis of Reading Ability have been calculated by Yule et al (1974). According to Goodacre (1971), different schools and LEA's use a variety of ad hoc procedures instead of regression formulae for this purpose.

The second way in which the WISC test is used is to provide a profile of an individual's strengths and weaknesses, which may be used to generate hypotheses about the nature and origin of a learning difficulty. The simplest way of doing this is to compare the Verbal with the Performance quotients. Sattler (1974) has reviewed the many studies in this area, which show, as far as children with reading and spelling difficulties are concerned, a slight tendency towards superiority on the Performance Scale.

However, the majority of such differences are small and therefore not of great diagnostic importance (although large verbal/performance discrepancies in either direction do require further investigation).

The Verbal Scale of the WISC and WISC-R includes two tests (Arithmetic and Digit Span) which at all age-levels correlate less well with the total verbal score than the other verbal sub-tests. Arithmetic, Digit Span and Information are the subtests in the Verbal Scale on which backward readers tend to obtain low scores, as shown by Rugel (1974) who brought together 25 relevant studies. If one considers the mean scores on the remaining verbal subtests (Comprehension, Similarities and Vocabulary) in Rugel's data, it is almost identical with the mean score on performance subtests. The figures are 10.39 and 10.36 respectively. This suggests that reading difficulty is not typically part of an overall language deficit, but that it is in a significant proportion of cases associated with problems in holding information mentally either for short or for long periods of time. The Digit Span test is a paradigm test of short-term memory for sequentially ordered information, and the Arithmetic test also makes substantial demands on immediate memory, insofar as the question has to be kept in mind while a series of numerical operations are carried out.

It appears, therefore, that it may be more profitable to consider the WISC profiles of children with learning difficulties in terms of three (or more) main categories rather than two. This view is supported by the majority of factor analytic studies which will now be considered.

Factor structure of the Wechsler tests.

Factor analysis of the Wechsler Intelligence Scale for Children has frequently yielded three or more factors (Gault, 1954, Cohen, 1959, Baumeister & Bartlett, 1962). There is general agreement about the nature of the verbal and spatial factors, but different names have been suggested for the third factor which has major loadings on Arithmetic, Digit Span and Coding. 'Memory', 'stimulus trace', 'freedom from distractibility', 'numerical ability' and 'sequencing' are among the labels that have been suggested by different writers. In this paper the term 'numerical sequencing' is used, as the test items all involve the processing of numbers in different kinds of sequence.

The factorial structure of the WISC-R is almost identical to that of the old WISC, and falls into the same clearcut pattern at all age levels between 6 and 16 (Kaufman, 1975). Mentally retarded children show essentially the same factor structure as normals (Baumeister & Bartlett, 1962, Osborne & Tillman, 1967, and Van Hagen & Kaufman, 1975), and most writers seem to assume that there are no significant sex differences.

The utility of this statistical analysis of the WISC for the applied psychologist has yet to be established. First, the calculation of factor scores is laborious. Second, the second and third factors each account for only a small proportion of the total variance (5-10% in the majority of studies). Third, the test-retest reliability of factor scores has not been calculated. Fourth, it is not known to what extent clinical groups differ in obtained factor scores.* Fifth, it is not clear how closely

* However, a recent unpublished study by Williams (1977) indicates that raw score approximations to the verbal and numerical sequencing factors (using the method to be described later in this paper) are both moderately good predictors of GCE 'O' Level performance, whereas spatial ability is largely irrelevant for most areas of the curriculum.

various combinations of scaled subtest scores might agree with factor scores. Cohen felt that the subtest specificity of the WISC was so low as to make subtest profile analyses virtually meaningless. Kaufman was more positive about the WISC-R, quoting an average subtest specificity quotient (proportion of variance) of 0.28.

The subtest profiles of backward readers.

Despite Cohen's warnings, the literature on WISC subtest profile analysis is extensive, and there are a great many studies comparing backward readers with controls (e.g. Belmont & Birch, 1966, Doehring, 1968, Lyle, 1969, Klasen, 1972, Moseley, 1972, Rugel, 1974). These studies generally agree in the finding that backward readers tend to do poorly on the subtests Arithmetic, Digit Span and Coding. In some studies, but not in Klasen's large sample of 488, Vocabulary is also depressed, and Information is also generally acknowledged to be one of the weaker points among backward readers. There are no doubt many reasons for this, including the limited access to verbal learning imposed by a reading problem, and perhaps relating to the nature of the reading problem itself in certain children with developmental language delays.

Lyle & Goyen (1969) argued that if poor performance on subtests like Information, Vocabulary and Coding were in large part the consequences of a reading problem, there should be a progressive relative decline in performance with age among backward readers. As they pointed out, there is no evidence of this. However, the argument is not really convincing, since it is pure guesswork to attempt to quantify the handicapping effects of a

reading disability in this kind of way. It is possible, for example, that older backward readers discover a greater variety of compensatory learning strategies to minimise the side-effects of their handicap.

A further complication in the interpretation of subtest discrepancies is socioeconomic status. The vast majority of poor readers have fathers in unskilled manual occupations, and Cropley (1964) found that both Vocabulary and Information were among the five WISC subtests which showed the greatest differences between high and low SES groups at 10 and 12 years. Deficiencies in Vocabulary and Information in children with reading problems from working-class backgrounds may be causally inter-related, but equally may both arise from a common cause or set of causes. One can, of course, apply similar arguments to Arithmetic, since children with reading problems are inevitably handicapped in working from arithmetic books, and there are also significant social class effects here. However, the WISC subtest is exclusively of mental arithmetic, and the relative weakness of backward readers on Arithmetic is so great (a mean difference of almost one standard deviation between 1,367 disabled readers and 554 normal readers in Rugel's review of 25 studies), that it does not make sense to attribute it to reading difficulties and to socioeconomic factors alone.

Many backward readers have difficulty on a wide range of tasks involving the rapid sequential processing of symbols (Doehring, 1968). Doehring compared 39 boys retarded in reading with 39 boys who were

average readers. Arithmetic, Digit Span and Digit Symbol were depressed in the retarded group, together with a variety of tests involving auditory sequencing skills and visual perceptual speed. A factor analysis showed that for the retarded readers, reading and spelling scores were correlated with other measures which involved the processing of both verbal and non-verbal sequences. The only Wechsler subtests which loaded on this factor were Digit Symbol (.55), Arithmetic (.55) and Digit Span (.48). For the normal readers, however, reading and spelling were not associated with visual perceptual speed, and while both Arithmetic and Digit Span loaded on the reading/spelling factor, Digit Symbol did not.

The key finding in Doehring's study was the strong link between the development of reading and spelling skills in backward readers with more general sequential processing skills. The WISC subtests which tap this area of ability are undoubtedly Arithmetic and Coding (which are timed) and Digit Span (where delay means failure).

A sex-difference in Coding.

We now have to ask whether the same pattern of weakness in the rapid processing of information holds for both boys and girls with reading problems. It turns out that the ratio of boys to girls among children with reading problems is so high that only one major study to date has been able to muster enough girls to justify looking at the WISC profiles of girls separately. Klasen (1972) reported data on 349 boys and 139 girls attending a centre for dyslexic children. The full-scale mean IQ

of the boys (107.1) was three points higher than that of the girls (104.1). Klasen found that both boys and girls were equally weak on Arithmetic and Digit Span, but whereas Coding ranked tenth out of 11 subtests for boys, it was as high as third for girls. The dyslexic boys scored below the girls on Coding by an average of one scaled score point ($\bar{x}$ 9.5 for the boys and $\bar{x}$ 10.5 for the girls). Similarly, Moseley (1972) found that Coding ranked seventh for 87 boys in need of remedial reading, but first for 23 girls. These apparently paradoxical results are less surprising when one looks at the data on sex differences in WISC subtests in a normal population. Wechsler (1949) did not provide figures for boys and girls separately, but Darley and Winitz (1961) found that Coding A ranked first for 75 normal kindergarten girls, but tenth for boys, with a mean difference of 2.23 scaled score points ($p < 0.01$). Similarly, with 9-10 year olds, Lyle & Johnson (1974) found a mean female superiority of approximately 2 points in a comparison of 41 girls and 44 boys who were selected at random, and who were not found to differ significantly on group tests of verbal and non-verbal ability. Furthermore, the superiority of females on the WAIS digit symbol subtest has been reported in a number of studies (Norman, 1953, Goolishion and Foster, 1954, Wechsler, 1958, Shaw, 1965). Wechsler found a mean sex difference of 1.12 scaled score points, the greatest for any subtest. There were no significant sex differences in the standard deviations obtained in any of these studies. It is therefore still possible that girls with reading difficulties are relatively poor at Coding when compared with other girls,

but some adjustment for a sex difference in this subtest will have to be made in any attempt to obtain a measure of numerical sequencing ability. On the basis of the Darley and Winitz, Lyle and Johnson and Shaw studies, one might decide to add one scaled score point for boys and to subtract one for girls. A more conservative adjustment, in line with Wechsler and Klasen, would be to add 0.5 for boys and to subtract 0.5 for girls.

If one adjusts the Coding scores of boys and girls by adding and subtracting 0.5 of a scaled score point respectively, the Coding subtest then turns out to be the third weakest subtest both for the 349 dyslexic boys and for the 139 dyslexic girls in Klasen's study, and the means for boys and girls to be identical. An adjustment of this order would not demolish the well-accepted finding that backward readers (most of whom seem to be boys in the proportion 2:1 or 3:1) tend to be poor at Coding, but a greater adjustment (adding and subtracting a full point according to sex) would do just that. Doehring's (1968) study in which 39 male retarded readers obtained a mean Coding score 1.3 points below 39 boys with normal reading, despite the fact that the two samples were well matched for overall performance IQ, certainly suggests that the smaller adjustment is appropriate.

Derivation and use of grouped subtest scores in profile analysis.

On the basis of the WISC factor studies mentioned above, three subtests with high loadings on each of the verbal, spatial and numerical sequencing factors were selected as providing a crude approximation to factor scores. Information was excluded from these groupings, as it contributed substantially both to the verbal and to the numerical

sequencing factors, and so was Picture Arrangement, which proved to be factorially complex, and showed a different structure at different age-levels. Mazes was also excluded from the analysis, as it also had different factor structure at different ages, and is, moreover, rarely administered in routine assessment. This led to the following groupings:

Comprehension Similarities Vocabulary	)	Verbal subtests (V)
Picture Completion Block Design Object Assembly	)	Spatial subtests (S)
Arithmetic Digit Span Coding	)	Numerical sequencing subtests (N)

Before the above groupings could be put to practical use, it was necessary to derive standard scores for each group separately, and also to provide a proper statistical basis for the evaluation of differences between V, S and N Scores.

The standardisation data provided in the WISC-R manual, relating to 200 children at each of 11 age-levels, was used in the derivation of the tables presented below.

The following formula was used for obtaining the combined variance of each group of subtests:

$$Vcom = V_a + V_b + V_c + \sum \begin{matrix} 2\, r_{ab}\, \sigma_a\, \sigma_b \\ 2\, r_{ac}\, \sigma_a\, \sigma_c \\ 2\, r_{bc}\, \sigma_b\, \sigma_c \end{matrix}$$

Percentile points were then derived for V, S, and N scores. The standardisation data provided in the WISC-R manual allows one to derive

separate tables for eleven successive age groups from 6½ to 16½ years. This was in fact done, but it was found that variation with age was minimal. Accordingly, a single table is given below, based on the full standardisation sample of 2,200 children. The percentile points given in this table are all within one point of the scores calculated for separate age-groups.

TABLE 1. Percentile points for V, S and N scores (with optional adjustment for sex-difference on coding subtest).

sum of s.s.	sum of s.s. (Adj.)*	Verbal Percentiles	Spatial Percentiles	No. Seq. percentiles	No. Seq. Percentiles (Adj.)*	sum of s.s.	sum of s.s. (Adj.)*	Verbal Percentiles	Verbal Percentiles	No. Seq. percentiles	No. seq. percentiles (Adj.)*
15	14.5	3	2	1	1	31	30.5	55	55	53	56
16	15.5	4	3	2	2	32	31.5	60	61	59	62
17	16.5	5	4	2	3	33	32.5	65	66	64	67
18	17.5	6	5	3	4	34	33/5	69	70	70	72
19	18.5	8	7	5	5	35	34.5	74	75	75	77
20	19.5	10	9	6	7	36	35.5	78	79	79	81
21	20.5	13	11	8	9	37	36.5	81	83	83	85
22	21.5	15	14	11	12	38	37.5	85	86	87	88
23	22.5	19	17	13	15	39	38.5	87	89	89	91
24	23.5	22	23	17	19	40	39.5	90	91	92	93
25	24.5	26	25	21	23	41	40.5	92	93	94	95
26	25.5	31	3-	25	28	42	41.5	94	95	95	96
27	26.5	35	34	30	33	43	42.5	95	96	97	97
28	27.5	40	30	36	38	44	43.5	96	97	98	98
29	28.5	45	45	41	44	45	44.5	97	98	98	99
30	29.5	50	50	47	50		45.5			99	

The standard error of the diference between means of two of the V, S and N groupings was calculated from the formula:

$$s.e._{diff.} = \sqrt{\frac{V\ com_1}{n} + \frac{V\ com_2}{n} - 2r_{12}\,\sigma_{m_1}\,\sigma_{m_2}}$$

Percentile points were then derived, showing the expected proportion of children with a given difference between V and S, V and N, and S and N scores (Table 2). It is important to note that these proportions are given in one-tailed form - i.e. if there are 5% of children in the general population with V scores higher than S scores by 11 points or more, there are also another 5% with S scores higher than V scores by the same amount. It is also important to note that a percentile point in Table 2 relates to the observed frequency of a discrepancy of a given order, not to the significance level of that discrepancy.

The statistical significance of differences between two groups of three, or between three and six subtests can be evaluated by Maxwell's (1959) method. In fact, for comparing three subtests with three others, the difference between sums of scaled scores has to be 14 to be significant at the $p < 0.05$ level, and when a group of three subtests is compared with one of six subtests, the difference has to be 12 to be significant at the $p < 0.05$ level.

TABLE 2. Percentile points for differences between V, S and N scores.

(The distribution given i. one-tailed.)

Diff.	V/S difference	V/N difference *	S/N difference *
0.5		47	47
1.0	44	44	45
1.5		42	42
2.0	39	39	39
2.5		36	37
3.0	33	33	34
3.5		31	32
4.0	28	28	30
4.5		26	37
5.0	23	24	25
5.5		22	23
6.0	19	20	23
6.5		18	19
7.0	15	16	17
7.5		14	16
8.0	12	13	14
8.5		11	13
9.0	9	10	11
9.5		9	10
10.0	7	8	9
10.5		7	8
11.0	5	6	7
11.5		5	6
12.0	4	4	5
12.5		3	5
13.0	3	3	4
13.5		2	3
14.0	2	2	3
14.5		2	3
15.0	1	2	2
15.5		1	2
16.0	1	1	2
16.5		1	1
17.0	0.7	0.7	1
17.5		0.6	1
18.0	0.5	0.5	0.8
18.5		0.4	0.7
19.0	0.3	0.3	0.5
19.5		0.3	0.5
20.0	0.2	0.2	0.4

* It is possible to allow for sex differences on Coding subtest by adding 0.5 for boys and subtracting 0.5 for girls before calculating differences between sums of scaled scores.

In order to illustrate the use and interpretation of Tables 1 and 2, in conjunction with Maxwell's method, an example is given below.

Similarities	12	
Vocabulary	14	
Comprehension	11	
Total	37	81st percentile
Picture completion	15	
Block Design	12	
Object assembly	13	
Total	40	91st percentile
Arithmetic	8	
Digit Span	6	
Coding	8.5 (adjusted)	
Total	21.5	12th percentile

The V/N difference of 15.5 points is found in only 1 per cent of the population, and is significant at the $p < 0.05$ level. The S/N difference of 18.5 points is found in only 0.7 per cent of the population, and is significant at the $p < 0.05$ level. The V/S difference of 3 points is both common and non-significant.

The interpretation of discrepancies between groups of subtests.

The method of analysing subtest scores proposed in this paper will prove to be of value only if (a) it helps to identify a group of children with learning difficulties of a particular kind, (b) it has practical implications for remediation.

Evidence is presented in Table 3 that the inferiority of backward readers on the N group of subtests is substantial. The data is taken from Rugel's paper, and is based on 21 studies of disabled readers (total number of subjects 1367) and 13 studies of normal readers (total number of subjects 554). On average, the N scores are approximately 2 scaled score points below the V and the S scores.

Table 3.

A comparison of mean WISC subtest scores of disabled and normal readers (from data summarised by Rugel).

		Disabled readers	Normal Readers
V	(Similarities	10.25	11.41
	(Vocabulary	9.85	11.56
	(Comprehension	10.34	11.26
S	(Picture Completion	10.98	11.03
	(Block Design	10.60	11.05
	(Object Assembly	10.62	12.03
N	(Arithmetic	8.60	11.55
	(Digit Span	8.31	10.65
	(Coding	8.95	10.39

The writer has applied the V/S/N analysis to two samples of backward readers. The first sample consisted of 87 boys of junior school age who were seen by educational psychologists before admission to LEA remedial centres. They all had Schonell or Burt reading quotients of less than 80, and I.Q.'s in the range 85-115. A comparison of the N and S groups of subtests showed that 46 of the boys (53%) had N scores more than 1.33 s.d. lower than their S scores. A discrepancy of this order would be expected in only 5% of a normal population. The corresponding figures for the N/V comparison were 35 boys (40%) with N scores more than 1.33 s.d. lower than V scores.

The second sample was a smaller clinic group of 26 boys receiving remedial help. Again, all had reading quotients of less than 80, the age-range was 6-14 years, and the I.Q. range 69-116. The majority of these children were weakest on the N group of subtests (19/26), and 12 of them (46%) had N/S or N/V discrepancies of 1.33 s.d. or greater. In both of the above samples the frequency of large V/S differences was almost exactly what one would expect by chance, both at the 5 percent and 10 percent cut-off points.

It appears then that a substantial proportion, probably more than one half of all children with reading problems, also have sequential processing difficulties affecting one or more of the following areas:

associative learning

auditory sequential memory

visual perceptual speed.

Relatively few (no more than would expect by chance) have specific difficulties affecting the areas of spatial or verbal ability.

The fact that it is possible to have a severe reading difficulty without any other problems in sequential processing argues against the idea that these problems may be the consequences of a failure to read. There are a number of hypotheses which have been put forward to explain certain types of reading difficulty in terms of deficiencies in underlying cognitive processes, produced through a variety of possible causes, such as maturational lag, genetic predisposition, brain damage, or emotional stress. The WISC profile alone, however, is of no value in attempting to make a judgement as to which of these hypotheses to favour in the individual case. The studies of Hopkins (1964) and Maxwell (1961) show that Arithmetic,

Digit Span and Coding are characteristically depressed both in children diagnosed as 'brain-injured' and as 'neurotic', but there has been no research attempt to disentangle these factors from other possible causes of reading difficulty, nor has there been an examination of WISC profiles in 'brain-injured' and 'anxious' children who do not have problems with reading or spelling.

The V/S/N method of WISC subtest analysis does not, then, enable us to establish the cause of a learning difficulty, but it does enable us to identify a group of children whose attentional and learning problems are not specific to reading alone, but extend to other types of task involving associative learning, auditory sequential memory and visual perceptual speed. The WISC subtest scores on Arithmetic, Digit Span and Coding may serve as a pointer as to the relative degree of impairment in each of these three functions, and confirmation may be sought through the use of further diagnotic tests or in the course of diagnostic teaching. The V/S/N approach does of course also enable the psychologist to identify children with extreme discrepancies between verbal and spatial abilities. He will then want to look at the child's history and to continue his assessment in an attempt to understand how the difference arose. A further group of children have no marked discrepancies at all. Here one might hypothesise that an explanation of a reading problem is likely to be found if one looks at environmental factors such as lack of parental interest, poor teaching, absence from or changes of school, or a conditioned anxiety reaction to books or to print. Further research is, of course, needed to see whether environmental factors such as these do apply more often in these cases.

It is not yet known whether the V/S/N profile leads to specific implications for remediation. However, there is every reason to suppose that it might. Pumfrey (1974) describes work carried out at Manchester in which it was established that poor readers in the first year of junior school tended to obtain especially low scores on the Visual Sequential Memory and Auditory Closure subtests of the Illinois Test of Psycholinguistic Abilities (Kirk et al, 1968). When a twelve-week remediation programme of non-reading activities designed to alleviate deficits in these two areas was carried out with 24 children, not only were there specific gains on the ITPA, but mean reading scores improved at between two and three times the rate of a control group presented with a number programme comprised of simple exercises. In this case a significant result was obtained, and transfer of training demonstrated, even though the remedial programme was given to all the children, whether or not they had a specific weakness in the two areas of skill. Unfortunately, the literature does not contain an example of the evaluation of individualised remedial programmes planned to take account of major individual strengths and weaknesses.

It may be that individualisation is important only below certain critical levels of skill, or at certain ages. The writer has been involved in two borough-wide screening and remedial intervention projects with first-year junior children. In both cases, individual remedial programmes were drawn up on the basis of a diagnostic test battery, and the overall reading gains made were highly satisfactory, being at the mean rate of 2.3 and 2.5 months per month of instruction in the two l.e.a's. It has not yet been possible, however, to compare these individualised approaches with others in which test profiles of strengths and weaknesses were not used.

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